

Management of Infants & Children with Hearing Loss

Marlene Bagatto, Au.D., Ph.D.

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Tel Aviv, Israel



Hearing Aid Fitting

“The goals of prescription are to improve the ability to hear and thereby facilitate the development of sensory and perceptual skills, receptive and expressive language, speech production and literacy, academic performance, and social-emotional growth.”

~Carney & Moeller, 1998

Babies are not Small Adults



Early hearing loss impacts communication development

- Maximize critical period

Small ears that are growing

- Account for changes in ear canal acoustics

Depend on caregivers for hearing aid use

- Cannot provide verbal feedback

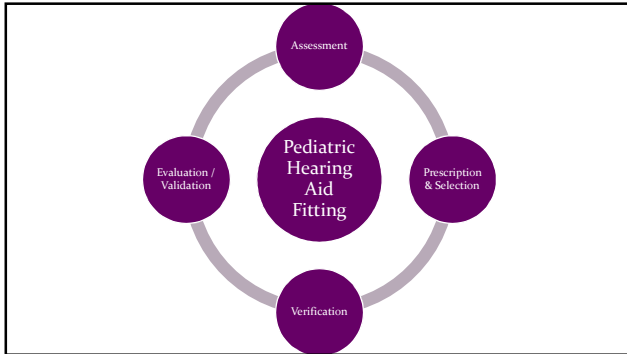
Early Hearing Detection & Intervention Programs

Goals:

- Identify infants with hearing loss and define the impairment by 3 months corrected age
- Initiate intervention by 6 months corrected age

Meeting the Goals

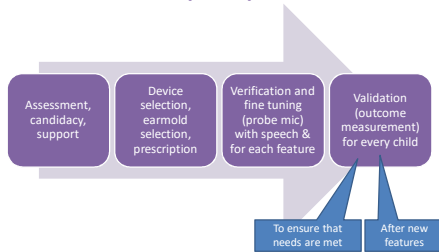
- **Evidence-based protocols** exist for:
 - thorough assessment of hearing in infants
 - accurate and suitable hearing instrument fitting in infants
- **Technology** exists for:
 - determining the degree, type, and configuration of hearing loss in infants
 - ensuring safe, comfortable, and appropriate levels of sound for infants with hearing loss



Provision of Hearing Aids

- Suitable technology and evidence-based hearing aid fitting guidelines and protocols support accurate and safe hearing aid fittings for the pediatric population
 - American Academy of Audiology, 2013
 - Australian Protocol; King, 2010
 - British Columbia Early Hearing Program, 2006
 - Modernizing Children's Hearing Aid Services, 2005
 - Ontario Protocol; Bagatto, Scollie, Hyde & Seewald, 2010; **Updated in 2014:** www.dsl.io.com
- JAAA Special Issue March 2016

AAA Pediatric Amplification Guideline (2013)

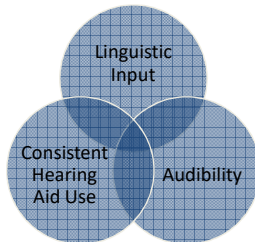


Examined the hearing, speech, language and psychosocial outcomes of children who are hard of hearing with respect to access to early intervention.

Boys Town National Research Hospital
University of Iowa
University of North Carolina

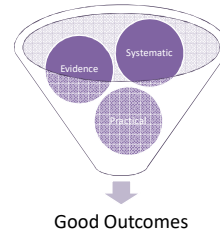
Factors Influencing Outcome

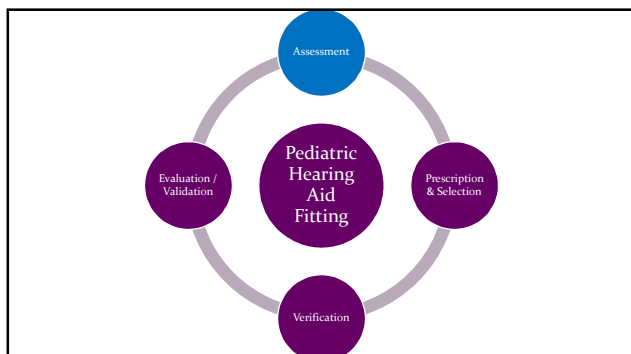
Outcomes of Children with Hearing Loss
Ear & Hearing, 2015



Moeller, Tomblin, McCreery, Walker, Arenas, Harrison, Sprattford, Bentler, Holte, Roush, Oleson, Van Buren, Ambrose, Unflat-Berry

Importance of Guidelines/Protocols





Essential Element: Complete Assessment

- Description of hearing in each ear is required prior to proceeding with hearing aid fitting
 - Degree, configuration, type
- Estimation of thresholds with air- and bone-conducted stimuli for at least two frequencies per ear
 - Include case history, otoscopic examination, immittance, diagnostic OAEs

Essential Element: Inserts for Assessment

- Use insert earphones for infant hearing assessment whenever possible
- It is more accurate and compatible with the target population



Range of SPL Reaching Eardrum

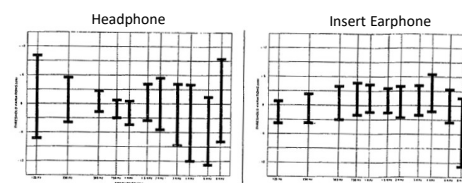


Fig. 1. The range of the supra-aural earphones with zero representing 80 dB SPL at the eardrum (variations from zero represent threshold variations).

Fig. 2. The range of the insert phones with zero representing 80 dB SPL at the eardrum (variations from zero represent threshold variations).

Gauthier & Rapisardi, 1992

Infant Hearing Assessment

- Infants under 6 months of age cannot perform behavioural hearing test

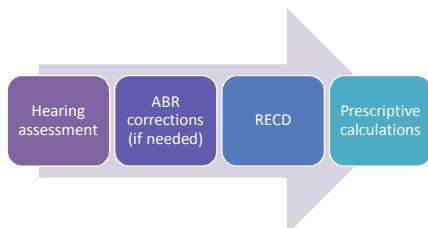


Audiological Evaluation: 0-6 months

- Estimates of hearing sensitivity are derived from FS-ABR measurements
- Hearing aid selection and fitting proceeds using ABR threshold estimates
 - Intervention is not postponed for collection of behavioural data



Assessment for Amplification



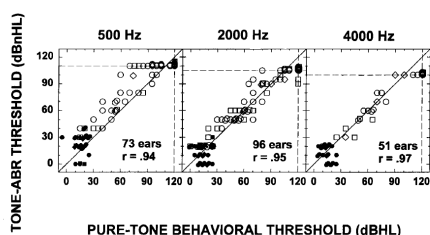
ABR vs. Behavioural Results

ABR threshold estimates (in **dB nHL**) have been shown to be higher than behavioural thresholds (in **dB HL**)

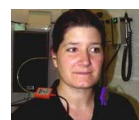
e.g., 10 – 20 dB in children with SNHL

Stapells et al 1995
Stapells 2000
Picton et al 1979

Stapells, Gravel, & Martin, 1995



Behavioural vs. Electrophysiological Assessment Procedures



- dB HL
- Entire auditory system
- Long duration pure tones
- Standard calibration



- dB nHL
- Measured from the brainstem
- Brief tone bursts
- Non-standard calibration

Estimating Infant Hearing Thresholds from the ABR

- ABR corrections are impacted by collection parameters, calibration, frequency, and differences between assessment strategies (e.g., electrophysiological vs behavioural)
- Inappropriate adjustments to ABR thresholds can lead to poor hearing aid fittings
 - Underestimation will lead to poor speech access
 - Overestimation will lead to exposure to unnecessarily high sound levels

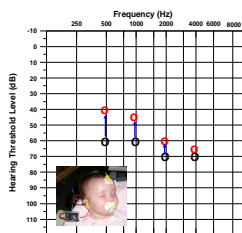
Tombilin et al 2014; Macrae 1994

A Clinical Solution

- For some ABR protocols, corrections from nHL to **Estimated Hearing Level (eHL)** are needed before intervention decisions are made
- The corrected nHL value represents a behavioural threshold (eHL) for the purposes of intervention

Essential Element: ABR Corrections

Ensure a smooth transition from electrophysiologic hearing assessment to early hearing aid fitting: *standardized nHL to eHL corrections, if needed.*



2005; Gorga et al 1993; McCreery et al 2015; Stapells et al 2005; Stapells 2000

Frequency-Specific Corrections (Ontario, 2016)

	AIR CONDUCTION				BONE CONDUCTION	
Frequency (Hz)	0.5k	1k	2k	4k	0.5k	2k
Minimum Level (dBnHL)	35	35	30	25	25 <1 yr 30 ±1 yr	30
Correction Factor	-10	-10	-5	0	0	-5

Correction factors are applied to ABR nHL values to obtain estimates of behavioural thresholds (eHL)

Western

Ontario Ministry of Children and Youth Services 2016

Converting nHL to eHL



- Ensure ABR (nHL) thresholds are only corrected once
- Indicate specific correction values to be used
 - Based on equipment type and parameter settings
- Anything else risks over- or under-amplification

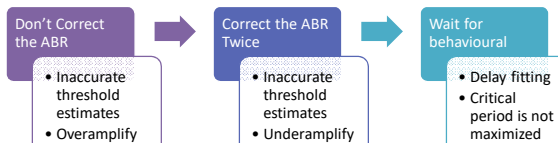
In our EHDl program, we decided on a plan for how our corrections are applied.

- The **Assessing Audiologist** applies the correction before plotting results on an audiogram. All results are discussed in eHL (not nHL) to better link to later assessment.
 - We have program-level corrections that are used at all sites. These are specific to our equipment and calibration.
- The **Amplification Audiologist** is trained that the corrections should already be done (so that it doesn't happen twice!).

Remember that the default corrections can be accessed in commercial systems. You can usually override these if you choose a different nHL to eHL correction.

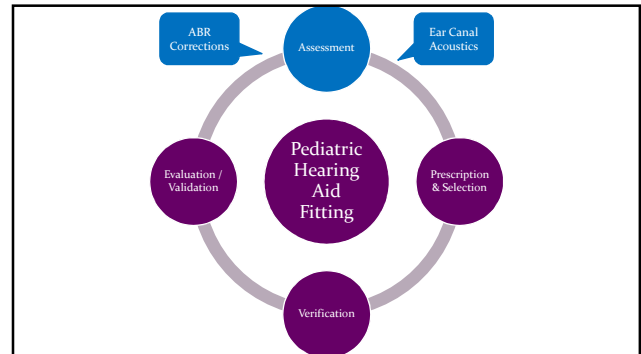


What happens if I...

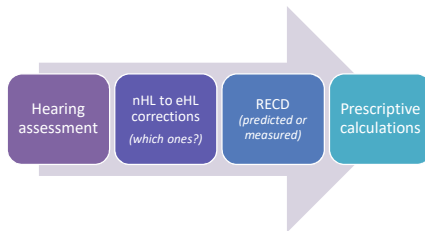


Take Home Message

- The most important thing is to use a correction at all.
- The second most important thing is to make sure it is not applied twice. Who will do it and how?
- The third most important thing is to use a correction that is appropriate for your system and collection parameters.



We also need to correct for ear canal acoustics.



Ontario Infant Hearing Program 2016; 2016;
American Academy of Audiology 2013

Insert earphones are the preferred transducer for infant assessments.

- It is more accurate and compatible with the target population
- Connect inserts to **personal earmolds** for follow-up audiograms
 - Better retention and acceptance
 - Sets you up for a more accurate hearing aid fitting
 - Earmold Audiogram
 - Earmold RECD

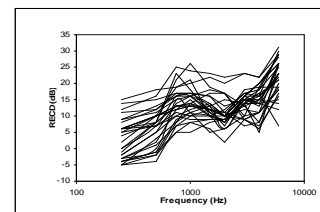


The RECD is a set of values that describe the acoustic characteristics of an occluded ear canal.

- Difference between SPL in a coupler and SPL your patient's ear canal
- Highly variable, especially in infants under 12 months of age
- Best practice for pediatric hearing aid fitting guidelines and protocols
 - Earmold coupling recommended



RECDs in Infants 2 to 6 months of age



RECD is used in two places:

HL Threshold + RECD + RETSPL
= Real-ear SPL Threshold

HL to SPL
Transform

SPLogram

Coupler SPL or gain + RECD + MLE
= Predicted Real-ear SPL or gain

Coupler
Verification

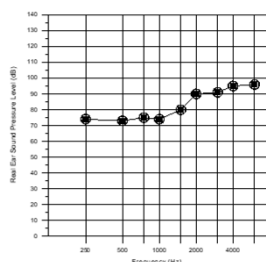
For BTEs this
needs to
account for the
earmold!

Gagne et al 1991; Munro et al 2001; 2003; Revit
1997; Scollie et al 1998; Moodie et al 2016

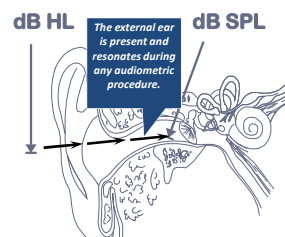
Measure Ear Canal Acoustics to Individualize Hearing Aid Fitting

- Real-ear measurements allow us to do this
 - Protects against errors in the fitting
- Real-ear measurement takes two forms:
 - Real-ear verification: Place the probe tube, verify hearing aid output in the ear.
 - Coupler verification: Same thing, but in a coupler with predictions to the real-ear. Common practice for pediatrics.

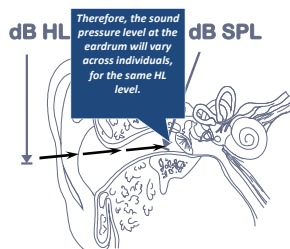
In real-ear SPL:



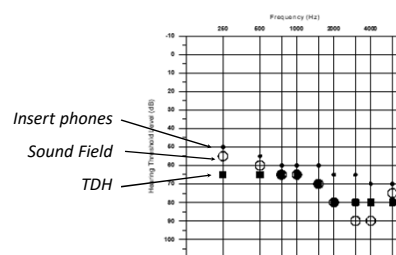
Why does it matter?



Why does it matter?

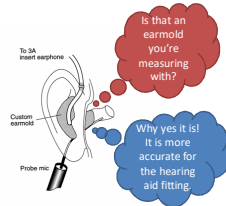


Different Transducer, Different HL Thresholds



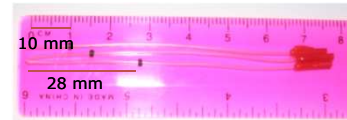
Probe-tube placement

- Place the tip of the probe tube within 3-5 mm of the eardrum



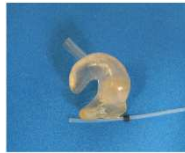
Constant Insertion Depth

- 30mm for adult males, 28mm for females
- 10-25mm for infants/children
- Hints:
 - Tape a ruler to your desk
 - Use a highlighter to mark a few depths along it



Customized Insertion Depth

- Identify the ridge of the earmold or hearing instrument corresponding to the location of the intertragal notch
- Lay the tube along the bottom of the earmold

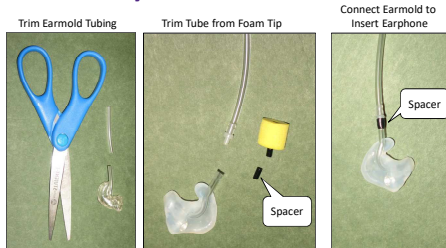


Customized Insertion Depth

- If you have some clear wrap or soft surgical tape, connect the probe tube to the earmold and insert it simultaneously
- To the active toddler, this may seem like you are only inserting the earmold



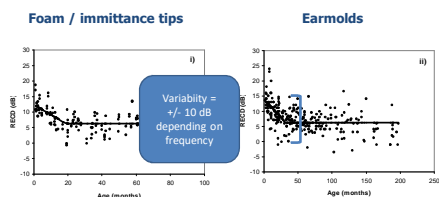
Audiometry & RECD with Earmolds



Variable Ear Canal Acoustics

- Large variability in ear canal SPL across infants and young children
 - Kruger 1987, Feigin et al 1989, Bagatto et al 2002
- Must account for this variability in both audiologic assessment and in hearing instrument fitting

Predicted RECDs



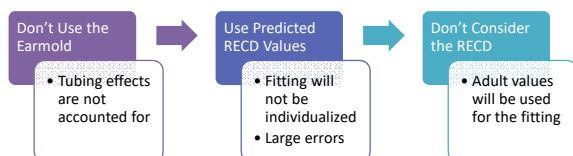
How often should RECDs be measured?

Each child's RECD values should be measured at the time of the initial fitting and monitored over time whenever possible

Rule of thumb:

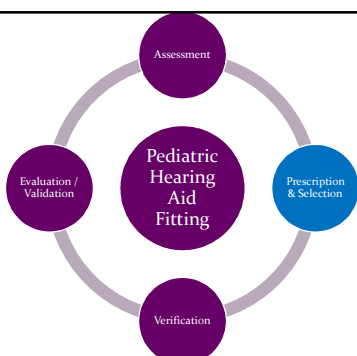
Measure RECD whenever the earmold changes

What happens if I...



Take Home Messages

- A measured RECD is necessary for an accurate description of your patient's ear canal which individualizes the hearing aid fitting
- RECDs are used to convert HL to SPL AND to allow for coupler-based verification
- Measuring audiometry AND the RECD with the earmold is best practice
- Predicted RECDs may be considered as a Plan 'B'



Essential Element: Evidence-Based Pediatric Fitting Formula

Evidence-based prescription: *can be used with any make/model of hearing aid and provides support for pediatric fittings.*



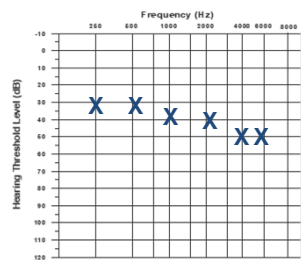
Objectives of Early Amplification

- Provide amplified signal that is audible for various input levels
- Avoid distortion
- Ensure availability of sounds across a broad frequency range
- Allow for sufficient electroacoustic flexibility
 - To account for changes in ear canal acoustics and/or auditory characteristics

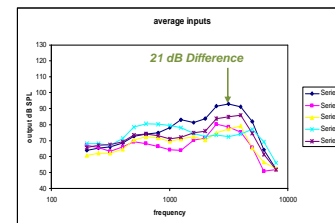
How similar are proprietary algorithms for fitting infants and young children ?

Seewald, RC, Mills, J, Bagatto, MP, Scollie, SD & Moodie, ST. (2008)
A comparison of manufacturer-specific prescriptive procedures for infants
Hearing Journal, 61(11):26, 28, 30, 32, 34.

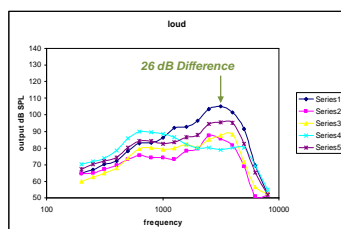
Variety of Audiograms: Sample Findings



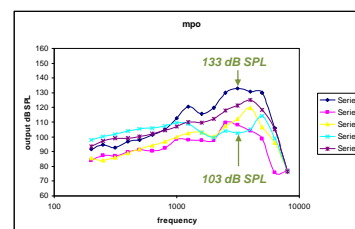
Output Targets: Average Speech Input



Output Targets: Loud Speech Input



Maximum Power Output Targets



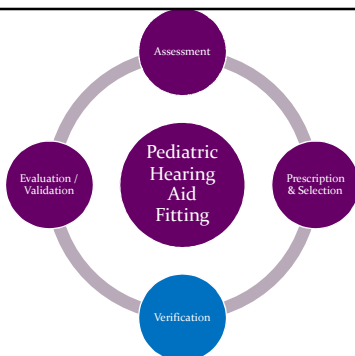
Listening Needs of Children with HL

- Children often experience hearing loss before or during the critical period of speech and language learning
- Children with hearing loss require more speech audibility than adults or children with normal hearing
 - E.g., Elliot, 1979; Gravel et al, 1999; Kortekaas & Stelmachowicz, 2000
- Children with hearing loss require more gain, a higher SNR and broader audible bandwidth of speech

Essential Element:

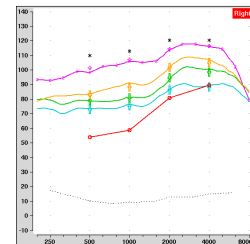
Evidence-Based Pediatric Fitting Formula

- Specific characteristics are required when fitting hearing aids to children:
 - Implementation of thresholds estimated from electrophysiological tests
 - Ability to account for ear canal acoustics
 - Age-specific normative data for predicting ear canal acoustics
 - Methods to support conducting coupler-based verification
 - Accounts for specific listening needs of the pediatric population



Essential Element: Real-ear Verification

Set the hearing aid for the infant **in the coupler**, focusing on the long term levels of conversational speech: *verify every hearing aid, and fine tune to target. Use speech-based equipment.*



Why Verify?

To provide the best possible fittings.

“The responsible audiologist wants to know as much as possible about the levels of amplified sound that hearing instruments deliver into the ears of infants and young children. To this end, the audiologist must apply comprehensive and evidence-based verification strategies that are compatible with the characteristics and capabilities of this unique population. **This is because the long-term implications of the fitting decisions we make are simply too important.**”

~ Richard Seewald

Goals for Verification

- ✓ Accuracy & reliability
 - Electroacoustic verification in the coupler
- ✓ Speech-like levels & MPO
- ✓ Infant-friendly procedures
 - There should be no requirement to sit up or respond behaviorally
- ✓ Meaningful displays
 - dB for dB comparison to thresholds & upper limits

Verification: Measurement Options

- I. Behavioural
 - Sound Field Aided Thresholds
- II. Electroacoustic
 - A. Real-ear Measures
 - 1. REIR
 - 2. REAR x Input Level
 - 3. RESR
 - B. Simulated Real-ear (coupler-based + RECD)
 - 1. Simulated REAR x Input Level
 - 2. Simulated RESR

Verification: Measurement Options

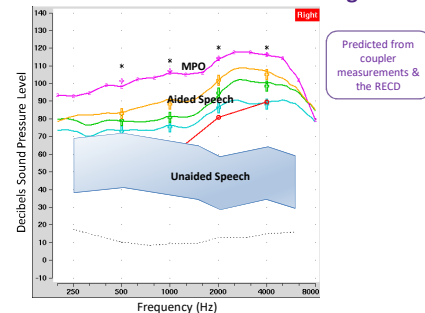
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Characteristics of the Aided Audiogram

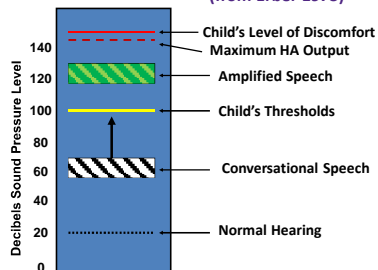
- No** • Does it tell us how the hearing aid processes speech?
- No** • **Suitable for Validation**
- No** • **Not**
- No** • **Verification**
- Yes** • It is meaningful?



Electroacoustic Verification - SPLogram



The Electroacoustic-based Approach to Fitting (from Erber 1973)



Clinical Implications

- Coupler measures & RECDs allow accurate and reliable prediction of real-ear hearing aid performance
 - Across ages
 - Across frequencies
- Reduces time/cooperation needed
 - Your patient must sit for ONE measurement
 - You already measured the for Assessment

RECD is used in two places:

HL Threshold + RECD + RETSPL
= Real-ear SPL Threshold

HL to SPL
Transform

SPLogram

Coupler SPL or gain + RECD + MLE
= Predicted Real-ear SPL or gain

Coupler
Verification

Gagne et al 1991; Munro et al 2001; 2003; Revit
1997; Scollie et al 1998; Moodie et al 2016

For BTEs this
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account for the
earmold!

What can happen when we don't use evidence-based fitting/verification protocols?



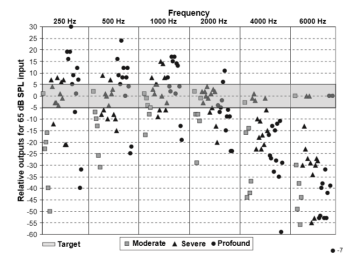
Hearing Instrument Fittings of Pre-School Children: Do We Meet the Prescription Goals?

Susan Strauss & Catherine van Dijk
International Journal of Audiology
2008



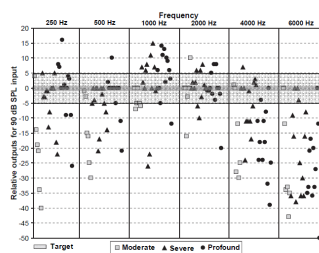
Strauss & van Dijk, 2008

65 dB SPL speech input
34 – 47% of fittings ± 5 dB of DSL Target



Strauss & van Dijk, 2008

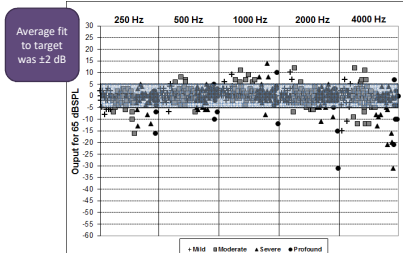
90 dB SPL narrowband input
34 – 39% of fittings ± 5 dB of DSL Target



92% were
 ≥ 5 dB
below DSL
target

Moodie et al, 2017

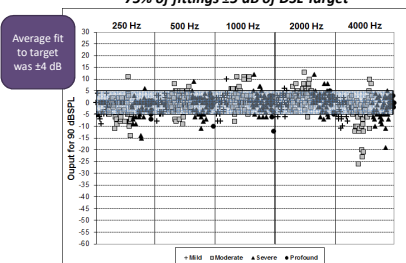
65 dB SPL speech input
80% of fittings ± 5 dB of DSL Target



Average fit
to target
was ± 2 dB

Moodie et al, 2017

90 dB SPL narrowband input
75% of fittings ± 5 dB of DSL Target



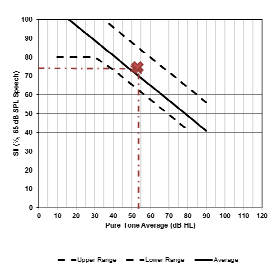
Good Consensus on Fitting

Fitting & verification	Canada	US	UK	Australia
Prescription	DSL v5.0	DSL or NAL-NL	DSL or NAL-NL	NAL-NL1
Measured RECD	Yes	Yes	Yes	Yes
Coupler-based verification	Yes	Yes	Yes	Yes
Broadband or speech signals	Yes	Yes	Yes	Yes

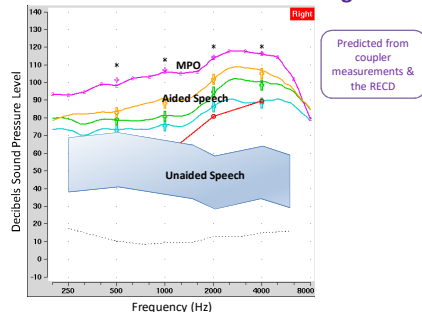
Other Analyses

- The Speech Intelligibility Index (SII)
 - An updated version of the Articulation Index (AI), standardized in 1997
- How to interpret:
 - 0 means no speech is audible
 - 1 means 100% is audible
 - This doesn't mean that 100% will be heard correctly.*

Pediatric Norms



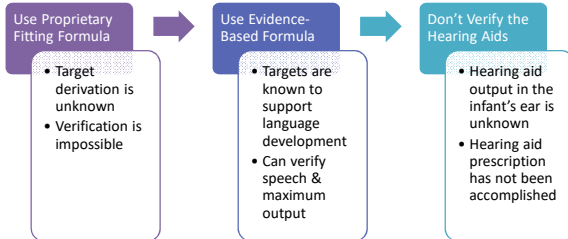
Electroacoustic Verification - SPLogram



Verification Protocol

- ✓ Obtain ear-specific hearing levels
 - Correct ABR if necessary
 - Use earmolds for follow-up behavioural assessments
 - Measure the RECD with earmold
- ✓ Calculate targets & select device
 - BTE with small filtered earhook & DAI
 - Lock controls & battery door
- ✓ Verify for speech & maximum output
 - Deactivate advanced technologies (& verify if activated later)
 - Coupler-based verification
- ✓ Follow up every 2-4 months
 - Outcome measures & reports from caregivers
 - Re-assess thresholds & RECDs (earmolds!) and re-adjust

What happens if I...



Essential Element: Special Considerations

Assess the unique needs of the infant & family: *carefully consider factors for mild & unilateral fittings, ANSD; assess the need for noise management & frequency lowering. Work with the family to support shared decision-making.*

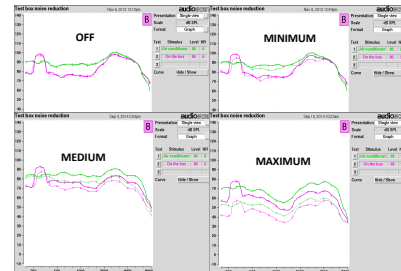


Ontario Protocols

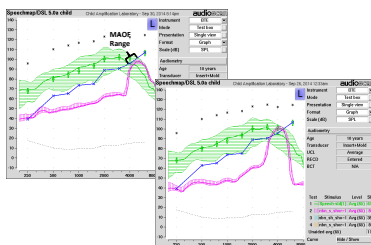
- Noise Management
 - Scollie et al, 2016, JAAA
- Frequency Lowering
 - Scollie et al, 2016, JAAA
- Candidacy themes:
 - Case-by-case
 - Factors to consider



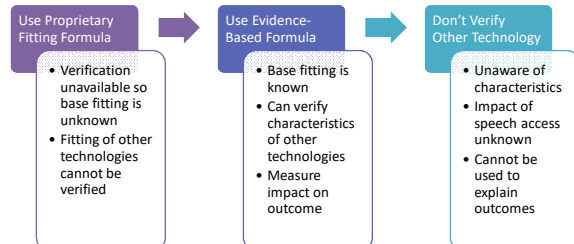
Strength of Noise Reduction Varies



Maximum Audible Output Frequency

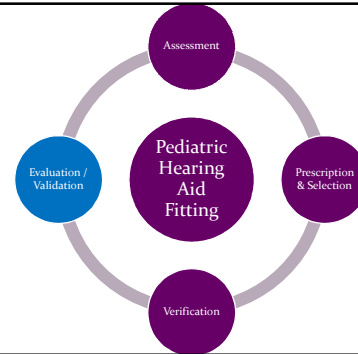


What happens if I...



Take Home Messages

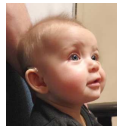
- RECDs are used to convert HL to SPL AND to allow for coupler-based verification
- Simulated REAR (in the coupler) is a valid way to assess hearing aid performance for children
- Consider other hearing aid technologies (noise reduction, frequency lowering) on a case-by-case basis
- If activated, verify the characteristics, impact on audibility and benefit
- This is most effective when starting with an evidence-based fitting formula



Essential Elements: Outcome Evaluation

At regular intervals, use age-appropriate outcome measures to assess the impact of the fitting:

demonstrates progress for the infant in the early stages of hearing aid use; continue to monitor throughout process.



Joint Committee on Infant Hearing Goal 6:

"All children who are D/HH should have their progress monitored every 6 months from birth to 36 months of age through a protocol that includes the use of standardized, norm-referenced developmental evaluations..."

~ JCIH, 2013

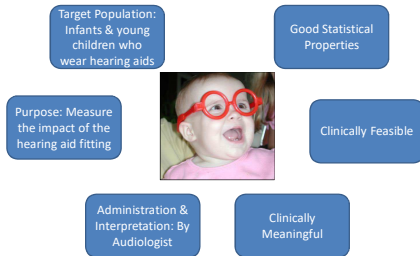
Clinical Need

Pediatric audiologists who fit young infants with hearing aids need tools to measure the impact of the hearing aid on the child's auditory development

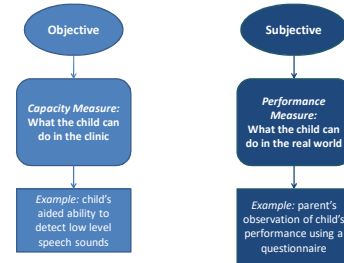
Program Need

Early Hearing Detection and Intervention (EHDl) programs need tools to assess the overall quality of the program

Considerations for Outcome Evaluation



Types of Outcome Measures



Version 1.0

Marlene Bagatto, Sheila Moodie, Susan Scollie
2010

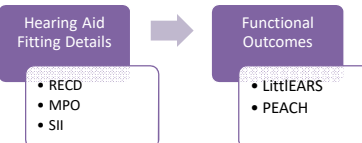
www.dslio.com

Contents of the UWO PedAMP

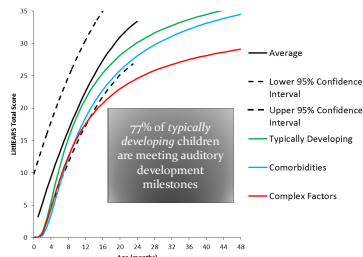
Tool	Purpose	Description
Amplification Benefit Questionnaire	<ul style="list-style-type: none"> Acceptance & use of hearing aids Satisfaction with services 	11 items 5 point rating scale
Hearing Aid Fitting Details	<ul style="list-style-type: none"> Quality of hearing aid fitting 	RECD, MPO, Speech Intelligibility Index (SII)
LittlEARS Auditory Questionnaire <i>Tsiakpini et al, 2004</i>	<ul style="list-style-type: none"> Receptive & semantic auditory behaviour Expressive vocal behaviour 	35 items Yes/no response
Parents' Evaluation of Aural/Oral Performance of Children (PEACH) <i>Ching & Hill, 2005</i>	<ul style="list-style-type: none"> Communication in quiet & noise Responsiveness to environment 	13 items 5 point rating scale

UWO PedAMP Development

- Avoid tools that:
 - are too lengthy or complicated
 - rely on information or scoring by other professionals (e.g., standard language measures)
 - May be implemented in other parts of the Early Hearing Detection and Intervention (EHDI) program
- Include tools that:
 - have good statistical properties
 - have good clinical feasibility and utility
 - support family-centered practice
 - help you collaborate better with others
- Maximize efficiency and interpretation through:
 - Visual tools to permit rapid scoring
 - Data to support interpretation

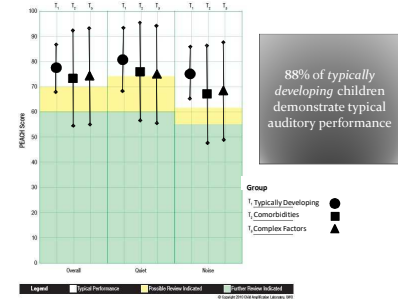


LittleEARS: Children with Hearing Aids

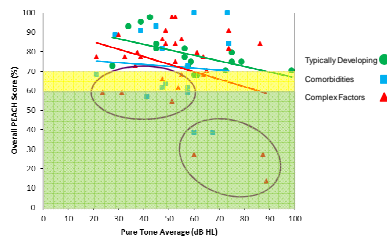


Bagatto et al, 2016

PEACH Scores for Children with Hearing Aids



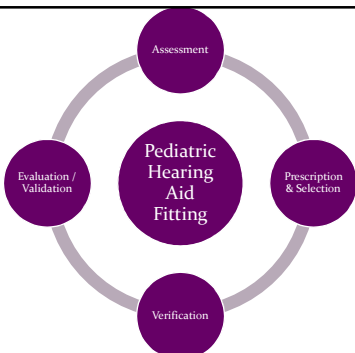
PEACH: Children with Hearing Aids



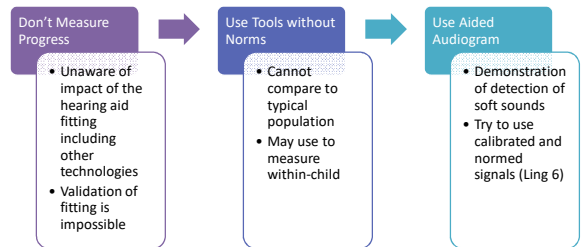
Bagatto et al, 2016

Objective Outcome Measures

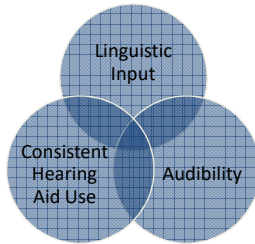
- Ling 6 (HL) Detection Task
 - Recorded and calibrated signals
 - Scollie et al, 2012
- UWO Plurals
 - Recorded and calibrated signals
 - Glista et al, 2012



What happens if I...



Good Fittings Contribute to Good Outcomes



“As caring and committed professionals, we must be vigilant about the possible audiological pitfalls that could be encountered during the confirmation of a child’s hearing loss, as well as during the audiological monitoring of that loss in the longer term.”

~Judith S. Gravel

bagatto@nca.uwo.ca

